CONSULTANT REPORT

PIER
Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

Buildings End-Use Energy Efficiency

HIGH EFFICIENCY LIGHTING TORCHIERES

Gray Davis, *Governor*

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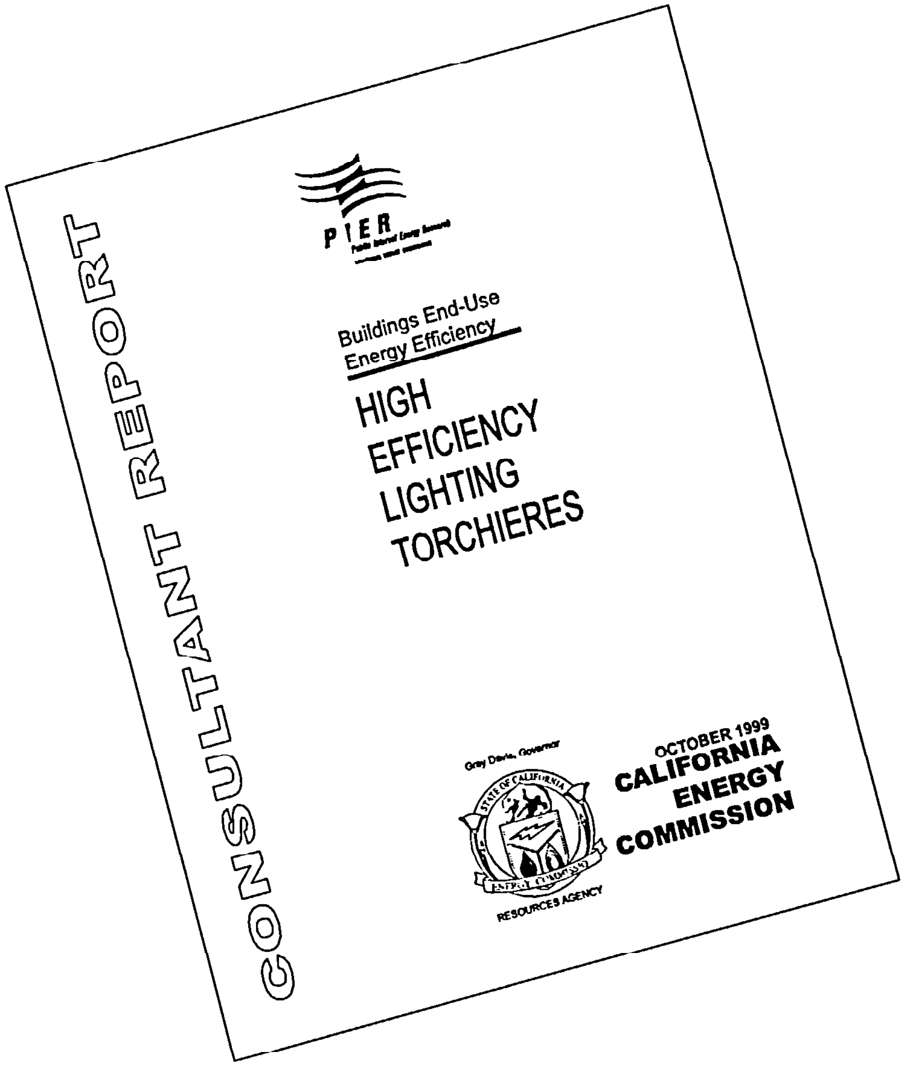

CALIFORNIA ENERGY COMMISSION

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million through the Year 2001 to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

In 1998, the Commission awarded approximately $17 million to 39 separate transition RD&D projects covering the five PIER subject areas. These projects were selected to preserve the benefits of the most promising ongoing public interest RD&D efforts conducted by investor-owned utilities prior to the onset of electricity restructuring.

What follows is the final report for the High Efficiency Lighting Torchieres, one of nine projects conducted by the California Institute for Energy Efficiency. This project contributes to the Buildings End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

Lawrence Berkeley National Laboratory (LBL) has been involved in the design and market integration of compact fluorescent torchieres since 1996. The need for research stems from the prevalence of very inefficient halogen torchieres in both the residential and commercial markets. The initial phase of this effort involved the development of the first compact fluorescent lamp (CFL) torchiere and integration of the CFL torchiere into the marketplace. The initial market penetration focused on residential markets, and included fixture manufacturer consultations, industry awards, and swap programs in colleges and universities.

This phase of the study concentrated on another potential CFL market where halogen torchieres have found widespread use. Commercial interiors, including office spaces, present the potential of major energy savings, and a unique set of lighting design challenges. As part of this study, torchieres were developed to replace halogen torchieres in commercial environments.

The primary goal of this study was to develop high-efficiency lighting torchieres using the latest high efficacy sources and advanced optical fixture designs. Specific objectives, outcomes and recommendations regarding this goal are briefly discussed in the following.

Project Objective

The objective of this project was to develop high efficiency lighting torchieres using the latest high output, high efficacy sources and advanced optical fixture designs, where:

- High efficiency means efficiency greater than 70 percent
- High output greater than 4,000 lumens
- High efficacy means efficacy of 70 to 80 lumens per watt*.

Project Outcome

We were able to develop high efficiency lighting torchieres that:

- Achieved efficiency greater than 70 percent in five out of six prototype units.
- Achieved output in the 4,000 lumens range in three of the six prototype units. In addition, it was discovered that the remaining three prototypes could achieve high output with the addition of another lamp, although this addition would result in a drop in efficiency and efficacy. (Appendix Data Sheets).
- At the time of the original proposal, we estimated the efficacy of the lamps would be in the 80-100 lumen per watt range. However when the first series of lamp prototypes were examined in the laboratory, the efficacy we measured was actually in the 70-80 lumens per watt range. Although somewhat lower than our original estimate, this still represents the highest efficacy obtainable for this size and shape of fluorescent lamp needed for high performance torchieres.

The below table provides examples of prototype features and market torchiere.

Prototype Features and Market Torchiere Examples

Torchiere name	Fixture Lumen output (lumens)	Power (watts)	Fixture efficacy (lumens/watt)	Fixture efficiency (%)	Up/Down Control? (Y/N)
Proto 1 (top)	3800	70	54	75	Y
Proto 1 (bottom)	1940	43	45	61	Y
Proto 2	3400	67	52	72	Y
Proto 3	2740	44	62	83	Y
Proto 4	3940	72	55	76	N
Proto 5 (electrodeless)	5710	102	56	71	N
Proto 6	3040	47	65	87	N
Current Market Torchieres:	2300-3000	55-60	42-50	60-77	N

Conclusions

- Results of this study suggest that there is considerable commercial potential for the new torchiere designs. This conclusion is based on the performance, the added functionality, and the considerable energy savings over halogen sources offered by these fixtures.
- Each of the prototypes had unique features well suited for specific applications.
- The different lumen outputs of these prototypes primarilly result from the number of lamps (and thus the power consumption) used in each fixture.
- In all three prototypes, the downlight element has been shown through testing to be less efficient than the uplight element, indicating an area where an investment in higher reflectance materials would be warranted.
- A reflector material study aimed at torchiere geometries demonstrated that lumen outputs can be increased by as much as 15 percent by using highly reflective materials, although the added cost of such materials may be an impediment in certain cost-sensitive application environments.

Recommendations

LBNL recommends the following steps designed to advance, commercialize and develop the high performance torchiere approach:

- Launch a follow-up research program on task lighting for office environments. The current approach involves DOE funding of the next concept development effort. This effort would be funded in FY2000.
- Conduct industry wide solicitation to advance the high output torchiere concept. Current efforts include the development of a web page dedicated to advanced torchieres and emerging technologies.
- Pursue individual contacts within the lighting and manufacturing industries to begin production development work on high performance torchieres
- Develop individual contacts with utilities and other large end-users to advance the technology. Currently we have contacted two large utilities with the concept of furthering the use of the high performance torchiere
- Pursue parallel efforts to advance the lighting approach developed in the high output torchiere project. LBNL has received funding for a new program on up/down table lamps utilizing this concept. LBNL expects to develop an entirely new table lamp system that grew out of the concept development work undertaken in the torchiere project.

Abstract

High output, high-efficiency, long life compact fluorescent lamps (CFL's) present promising new opportunities for torchieres when used in fixtures with well-designed optics and controls. Lawrence Berkeley National Laboratory (LBL) designed, built, and photometrically tested new torchiere designs that exploit the unique properties of these lamp sources in novel ways while providing high performance characteristics. The new designs are optimized for commercial office space interiors, consistent with a need in these spaces for indirect, low glare illumination with high color quality. Additional functionality includes the incorporation of a user controllable down-light component that provides direct task lighting. This allows a single, portable fixture to satisfy a multitude of office illumination requirements.

1.0 Introduction

Lawrence Berkeley National Laboratory (LBL) has been involved in the design and market integration of compact fluorescent torchieres since 1996. The need for research stems from the prevalence of very inefficient halogen torchieres in both the residential and commercial markets. The first phase of this effort involved the development of the first compact fluorescent torchiere and the integration of the compact fluorescent lamp (CFL) torchiere into the marketplace. The initial market penetration focused on residential markets, and included fixture manufacturer consultations, industry awards, and swap programs in college universities.

This phase of this effort concentrated on another potential CFL market where halogen torchieres have found widespread use. Commercial interiors, including office spaces, present the potential of major energy savings, as well as a unique set of lighting design challenges. These commercial spaces were identified as the focus of this second part of the study, and torchieres were developed with the specific goal of replacing halogen torchieres in these commercial environments.

The primary goal of this study was to develop high efficiency lighting torchieres using the latest high efficacy sources and advanced optical fixture designs.

1.1 Project Objective

The objective of this project was to develop high efficiency lighting torchieres using the latest high output, high efficacy sources and advanced optical fixture designs, where:

- High efficiency means efficiency greater than 70 percent
- High output means output greater than 4,000 lumens, and
- High efficacy means efficacy of 70 to 80 lumens per watt.

2.0 Technical Discussion

2.1 Technical Approach

2.1.1 Identify/Acquire High Output, High Efficacy Fluorescent Sources

With partners in the lamp industry, a number of high efficacy sources were identified as appropriate to this study. Considerations included lamp efficacies, total lumen outputs, lamp geometries, industry availability, and current lamp applications. A short list was generated, and after initial testing and evaluation, two different lamp systems were chosen as the most promising for further development. These include 22 watt (W) and 40W T-5 circline lamps from Philips, and 100W and 150W inductively coupled electrodeless (ICE) lamps from Osram Sylvania. Also included was the acquisition of the ballast and lamp socket hardware.

Initial forecasts estimated that lamp source efficacies would fall in the 80 to 100 lumens/watt range. These forecasts were based on consultation with industry representatives, and the advent of electrodeless T-18 lamps from Philips. Photometric tests showed that these efficacy estimates were higher than actual results, with lamp efficacies for the chosen sources falling in the 74 to 80 lumens/watt range.

2.1.2 Characterize Photometric and Electrical Performance

Each of the lamps acquired for the study was prepared for testing by 'burning' it in (turning it on) for 100 hours. This assured that light output was consistent with the output typically seen over the service life of the lamp. The lamps were then characterized in LBL's integrating sphere, a device that yields the total light output, in lumens, of a given source.

This task was delayed by an upgrade of testing equipment in the laboratory. This upgrade included refurbishment and recalibration of the integrating sphere and associated equipment, and the LBL Lighting Laboratory's goniophotometer, a device used in a later portion of the testing. These improvements were performed outside this project's budget.

2.1.3 Develop Advanced Optical Designs

The first level of this task was to identify possible market applications for new torchiere designs, and direct the new designs at best meeting those market needs. Early discussion led to the concept of an office torchiere that incorporated both up and down components of light. This concept is described in the following section.

2.1.3.1 Office Torchiere

Office workstations typically require different light sources for different tasks. The use of computer monitors ideally requires diffuse, ambient light with low screen glare effects, while printed materials require more light directed to a specific task plane (typically a desk surface) to avoid low light level eye fatigue. Straight tube fluorescent surface mount or recessed ceiling fixtures are common sources of ambient office light, sometimes also providing adequate or less than adequate reading light for printed materials. To complement this ambient light, a direct component of illumination is often provided by a desk table light or under-shelf fluorescent strip light.

The Office Torchiere addresses office illumination requirements by providing separate, user-controllable light sources for both an ambient, 'up' light component and a direct, 'down' light component in a single, movable fixture (Figure 1). Each component can be fully dimmable, allowing for a broad range of illumination configurations to meet different application demands and also allowing for energy savings by reducing unnecessarily high illumination levels.

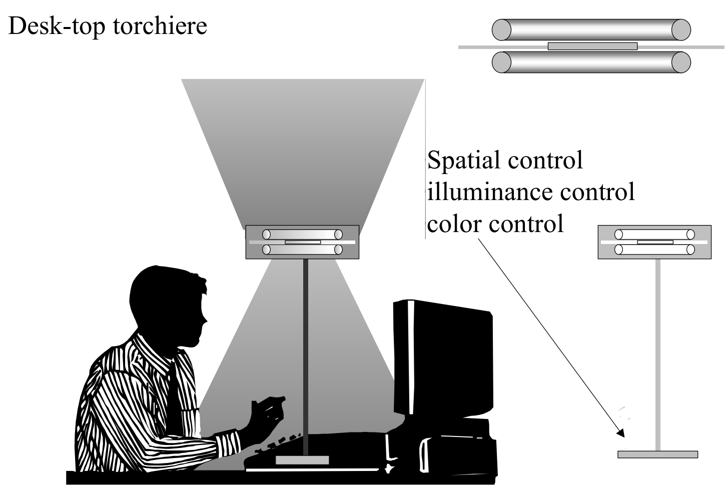

Figure 1. Torchiere Use

2.1.4 Design Prototype Torchiere Fixture

With this concept in mind, LBL started generating prototype designs for the chosen lamp sources. To adhere to current market designs, the basic geometry and scale of popular market torchieres was used as a starting point for the new designs. This included basic dish dimensions as well as overall fixture depth. From here, allowances were made for a down-light component that would illuminate a task plane below the plane of the fixture head without casting a direct component of light upward. Different shade shapes were drawn and geometries chosen based on anticipated performance characteristics and also on perceived aesthetic qualities. In all, approximately 15 different designs were generated for initial prototype development.

2.1.5 Construct Prototype Torchiere Fixtures

With conceptual initial torchiere designs completed, work began on generating computer-aided drafting (CAD) engineering drawings for the components required to assemble these designs. Developments of three-dimensional parts were generated to allow for ease of manufacture and reduce or eliminate any special tooling or fabrication costs. Components were laser cut from flat steel sheet stock by LBL's sheet metal shop. These sheets were then rolled and welded into the final fixture body shapes. The fixture bodies were painted by

LBL's paint shop with 80 percent reflective flat white paint on all relevant reflective surfaces.

The next step included assembling the fixture bodies onto upright posts and affixing the assemblies onto sturdy bases. Wiring and ballasting the chosen source lamps into place completed the prototypes and cleared the way for photometric testing of the new designs.

The 40W and 22W T-5 circline lamps used in this study were manufactured by Philips Lighting Company. The ballasts used were manufactured by either Philips or Advance Transformers, and both are industrial quality, fully dimmable systems. As such, these ballasts are relatively large and heavy, and may not easily lend themselves to packaging into smaller, torchiere style bases. Discussions with industry representatives have revealed that Philips is considering the development of smaller dimmable ballasts for these lamps, although no production times currently exist. This need not, however, be an impediment to the implementation of this technology, as the current trend in ballast technology is toward miniaturization, and manufacturers have the capability to custom build ballast systems to meet specific physical size limitations.

2.1.6 Photometric Evaluation of Prototypes

Prototype fixtures were tested in the LBL Lighting Laboratory's goniophotometer. The goniophotometer and associated software programming were recently upgraded and recalibrated, making the multiple tests performed faster and more accurate. This testing yielded fixture lumen distribution plots and total lumen outputs. This made possible the determination of fixture efficacies (the total lumen output of a fixture per watt of electrical energy input) and fixture efficiencies (the ratio of lumen output of a fixture to the lumen output of a bare bulb of the same type). This is the primary scientific data generated by this study, the details of which will be discussed in Section 2.2 of this report.

Several factors influence the efficiency of a given optical fixture. The reflectance and spectral properties of reflector surfaces determine the efficiency with which light is reflected from the inside surfaces of a fixture and thus the total amount of light that escapes the fixture to illuminate a given task plane. The shape of a reflector surface also influences this property in much the same way. To optimize the prototype designs generated, allowances were made for studying the effects of these factors on total lumen outputs. This was done by a reflector surface study aimed specifically at torchiere type geometries and by fabricating the prototypes to allow for reflector surface adjustability and optimization. Further, lamp placement within the fixture was also considered a variable and different positions and lamp combinations were tested to determine which produced the highest fixture efficiencies and efficacies.

2.1.7 Construct Final Manufacturing Prototypes

Data acquired from photometric evaluations was used to select the highest performance torchieres out of the group of prototypes originally constructed. Reflector geometries and lamp positions were fixed to give maximum lumen outputs and fixture efficiencies. LBL's shops were again contracted to provide additional parts and painting services, and final manufacturing prototypes were assembled and hardwired for demonstration purposes.

In all, six torchiere styles were chosen as candidates for final manufacturing prototypes. Four incorporated both up and down illumination components, while two were designed to be placed adjacent to a wall (as on a shelf) and provide only an uplight component.

2.1.8 Photometric Evaluation of Final Manufacturing Prototypes

The details and features of each of these fixtures will be provided in Section 2.2 of this report. The photometric testing procedure in this phase was identical to the photometric testing outlined in Section 2.1.6 above.

2.2 Technical Findings

Six initial prototype torchiere designs were chosen for development as final manufacturing prototypes. The performance characteristics of each are discussed in this section, with each design given separate consideration and comment. As a control feature to this experiment, two common torchiere units available on the market were used for comparison. One was the Emess 55W torchiere using a 2C style lamp (Figure 2), and the other was GE's Profile torchiere using a 60W 2D lamp (Figure 3). The lumen outputs ranged from 2300 to 3000 lumens, with fixture efficacies falling between 42 to 50 lumens/watt.

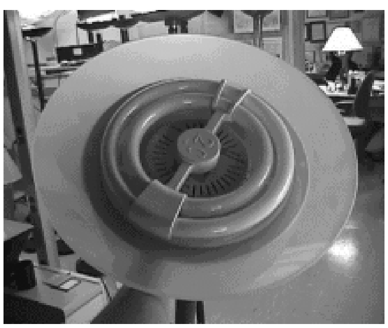

Figure 2. Emess's 55W Torchiere

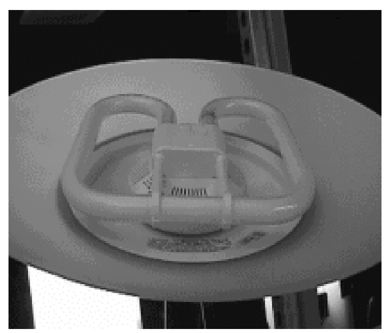

Figure 3 GE's 60W Profile Torchiere

Standard flat white paint was chosen as the coating material for all reflector surfaces. This decision was made to allow relative comparisons between prototypes, and to demonstrate that good efficiencies are attainable with low cost reflector coatings. The reflectance of this paint is approximately 80 percent. A separate reflector study was conducted to show the affect of using higher reflectivity materials on lumen outputs in typical torchiere geometries. This material is provided in Appendix I of this report. The data collected shows that fixture efficacies and efficiencies scale nearly linearly with the increase in reflectivity of the materials used. With a 95 percent reflective aluminum (Alanod) insert, this translates into a gain of approximately 15 percent over the use of standard white paint. This gain would be expected to apply to all of the prototypes if highly reflective (and higher cost) inserts were used. The reflector study description and data are contained in Appendix I.

2.2.1 Prototype 1

Prototype 1 is an up/down office torchiere with a 40W and a 22W T-5 circline lamp combination in the torchiere dish on top and a 40W T-5 circline lamp in the 'lamp shade' on the bottom. Philips manufactured the lamps. The optimized lamp combination on the top included bi-level lamp positioning and a central reflector cone (Figure 4). The bi-level lamp position has the 40W lamp raised approximately .75" with respect to the 22W lamp and was found to minimize lamp surface absorption losses when the two lamps were used in combination. Further, the central reflector cone, coated with standard (inexpensive) flat white paint, was found to boost output in this configuration. The total lumen output of this combination is ~3800 lumens with a fixture efficacy of 54 lumens per watt (lm/W).

The down light component has been added with a 40W lamp in the bottom of the fixture (Figure 4). This causes both the overall fixture efficiency and efficacy to drop, and is due primarily to light losses from the bottom lamp's deep fixture placement (necessary to eliminate direct bulb glare) and absorption losses from the fixture post (necessary to suspend the fixture). The use of high reflectance materials would help alleviate these losses, although the added cost of such materials would need to be justified from a market standpoint. With both the up and down light components, the total lumen output of this fixture is ~5500 lumens, with user control over the intensity and distribution of those lumens.

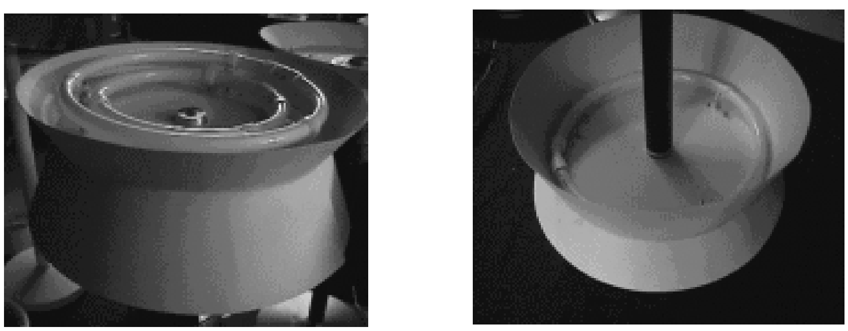

Figure 4. Prototype 1 (top and bottom)

2.2.2 Prototype 2

Prototype 2 shares several features with Prototype 1, with different geometric dimensions (Figure 5). The principle difference between the two is the vertical side reflector for the lower lamp on this torchiere, which limits this down light portion to the use of the 22W T-5 circline. The entire fixture is slightly smaller than the first, and may be considered more aesthetically pleasing. Lumen output is also lower due to the use of a single 40W lamp on top and a 22W lamp on the bottom.

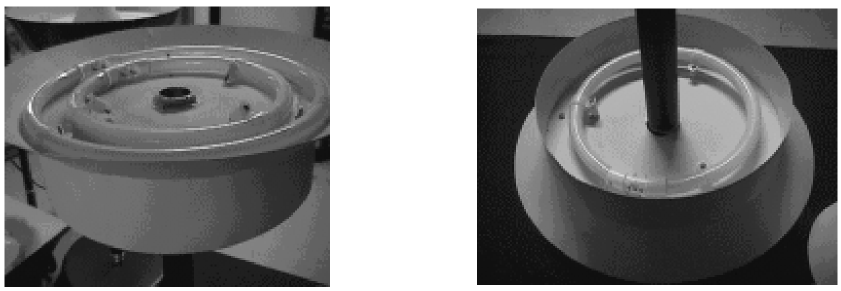

Figure 5. Prototype 2 (top and bottom)

2.2.3 Prototype 3

Prototype 3 has both an up and a down light component. Prototype 3 was developed with a manually controlled slider plate that selectively reflects light either up or down depending on the slider position (Figure 6).

Figure 6. Prototype 3

This torchiere exhibits good fixture efficiency and approximately 2700 lumen output with a single 40W lamp. An additional 22W lamp may be added to boost total lumen output.

It is anticipated that this fixture would cost the least of the three up/down office torchieres due to the simplicity of design and requirement for only one ballast (or two with two lamps) and associated wiring.

2.2.4 Prototype 4

Additional torchieres were developed that have only an uplight component. Prototype 4 is based on an asymetrical design intended to be placed against a wall, a common location for torchieres (Figure 7). The canted face and tilted lamp position direct the lumen distribution away from the wall and into the room, lowering brightness on the wall and more evenly distributing the light throughout the room. Again, fixture efficiency and efficacy is high, with 2800 lumens (lm) output from a single 40W lamp.

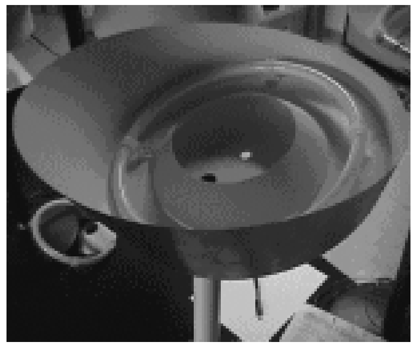

Figure 7. Prototype 4

2.2.5 Prototype 5

Prototype 5 utilizes Osram Sylvania's ICE lamp (Figure 8). The 100W T-18 lamp displays excellent lifetime characteristics (100,000 hrs rated) and high lumen output. The fixture developed for this lamp is a box type fixture that mimics the rectangular dimensions of the lamp itself, and is intended to be placed on a shelf or can be optionally mounted on top of a support pole to match common torchiere configurations. The output of this fixture is 5710 lm and is well suited for applications requiring high lumen outputs and low maintenance costs. This lamp is currently non-dimmable, but discussions with marketing and engineering personnel from the manufacturer (Osram Sylvania) indicate that future development of their inductive lamp technology will include development of dimmable ballast systems.

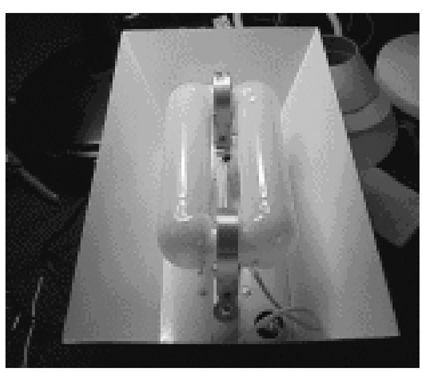

Figure 8. Prototype 5

2.2.6 Prototype 6

Prototype 6 incorporates a 40W T-5 Circline into the translucent dish torchiere style used by both the Emess and GE torchieres (Figure 9). Originally performed as a control experiment, the results show that this torchiere dish style is very efficient in fixture lumen output vs. bare bulb lumen output. Also of note is the relatively large amount of lumen distribution underneath the fixture head. Further development of this lamp and dish style would, however, need to address issues of bulb glare with suitable reflectors and/or diffusers, as the brightness of the bulb through the translucent dish is considered unacceptably high (~100 candellas in the plane of the fixture head).

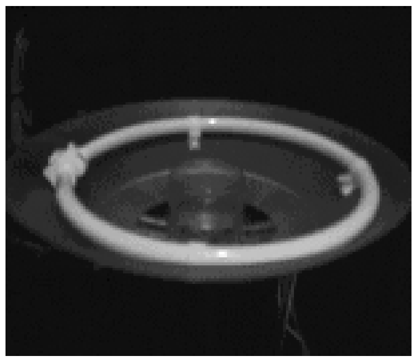

Figure 9. Prototype 6

3.0 Project Outcomes

We were able to develop high efficiency lighting torchieres that:

- Achieved efficiency greater than 70 percent in five out of six prototype units.
- Achieved output in the 4,000 lumens range in three of the six prototype units (Table 1). In addition, it was discovered that the remaining three prototypes could achieve high output with the addition of another lamp, although this addition would result in a drop in efficiency and efficacy. (Appendix Data Sheets).

3.1 General Findings

Table 1 provides a summary of the main features of Prototypes 1 through 6 and market torchieres. The results for Prototype 1 have been divided into two parts (up light and down light), while the results for Prototype 2 are given with both the top and bottom lamps in the fixture turned on. This is a result of the testing procedure, and reflects the best results obtained.

Table 1. Prototype Features and Market Torchiere Examples

Torchiere name	Fixture Lumen output (lumens)	Power (watts)	Fixture efficacy (lumens/watt)	Fixture efficiency (%)	Up/Down Control? (Y/N)
Proto 1 (top)	3800	70	54	75	Y
Proto 1 (bottom)	1940	43	45	61	Y
Proto 2	3400	67	52	72	Y
Proto 3	2740	44	62	83	Y
Proto 4	3940	72	55	76	N
Proto 5 (electrodeless)	5710	102	56	71	N
Proto 6	3040	47	65	87	N
Current Market Torchieres:	2300-3000	55-60	42-50	60-77	N

Prototype 1 offered the highest available lumen output of the three because of its capacity to hold a 40 watt lamp on the bottom. Prototype 2, a slightly smaller version, offered a different aesthetic quality potentially more desireable to architects or designers. Prototype 3 was suitable for low cost applications where a reflector position was manually set and not often adjusted. In all three prototypes, the downlight element has been shown through testing to be less efficient than the uplight element, indicating an area where an investment in higher reflectance materials would be warranted.

Prototype 4 is a low-cost, single or double lamp system that is intended for placement against a wall, a common location for torchieres. The lumen output of this fixture is directed away from the wall and out toward the room, reducing wall glare and more efficiently using the available light to illuminate a given space.

Prototype 5 uses Osram Sylvania's inductively coupled electrodeless (ICE) lamp in a box type configuration. These lamps, while relatively expensive, offer excellent lifetime characteristics and good color rendering. The developed fixture is intended for wall-mount or shelf-mount positioning where high lumen outputs are desireable and maintenance costs are prohibitive. The ICE lamp represents a new technology that has yet to see widespread application and associated economies of scale, but offers efficacies and lifetime qualities that are at the leading edge of fluorescent technology.

Prototype 6 represents new T-5 lamps applied in a currently popular torchiere dish style. Elevated levels of performance have been achieved with small investments in new optics systems.

4.0 Conclusions and Recommendations

4.1 Conclusions

Results of this study suggest that there is considerable commercial potential for the new torchiere designs. This conclusion is based on the performance, the added functionality, and the considerable energy savings over halogen sources offered by these fixtures.

Each of the prototypes had unique features well suited for specific applications. Prototypes 1, 2, and 3 offer user control over the light distribution of the fixture, incorporating a downlight feature that can be employed in much the same way as a table lamp while still offering an uplight feature well suited to office environments where computer screen glare must be kept to a minimum. The different lumen outputs of these prototypes primarilly result from the number of lamps (and thus the power consumption) used in each fixture.

Prototype 5 uses Osram Sylvania's inductively coupled electrodeless (ICE) lamp in a box type configuration. These lamps, while relatively expensive, offer excellent lifetime characteristics and good color rendering. The developed fixture is intended for wall-mount or shelf-mount positioning where high lumen outputs are desireable and maintenance costs are prohibitive. The ICE lamp represents a new technology that has yet to see widespread application and associated economies of scale, but offers efficacies and lifetime qualities that are at the leading edge of fluorescent technology.

All six prototypes used low-cost reflector and diffuser sytems to achieve performance qualities equal to or better than currently available market torchieres. All except one had reflector surfaces painted with standard white flat paint with a reflectance of 80 percent. A reflector material study aimed at torchiere geometries demonstrated that lumen outputs can be increased by as much as 15 percent by using highly reflective materials, although the added cost of such materials may be an impediment in certain cost-sensitive application environments.

4.2 Recommendations:

LBNL recommends the following steps designed to advance, commercialize and develop the high performance torchiere approach:

- Launch a follow-up research program on task lighting for office environments. The current approach involves DOE funding of the next concept development effort. This effort would be funded in FY2000.
- Conduct industry wide solicitation to advance the high output torchiere concept. Current efforts include the development of a web page dedicated to advanced torchieres and emerging technologies.
- Pursue individual contacts within the lighting and manufacturing industries to begin production development work on high performance torchieres
- Develop individual contacts with utilities and other large end-users to advance the technology. Currently we have contacted two large utilities with the concept of furthering the use of the high performance torchiere
- Pursue parallel efforts to advance the lighting approach developed in the high output torchiere project. LBNL has received funding for a new program on up/down table lamps utilizing this concept. LBNL expects to develop an entirely new table lamp system that grew out of the concept development work undertaken in the torchiere project.

Appendix I — Diffuse Reflective Torchiere Study

Appendix II Test Results